Announcements

- Homework for tomorrow…

  Ch. 30: CQ 10, Probs. 18, 20, & 22

  CQ3: The answer lies in your (recently used) garden hose (look inside while turning it on).

  30.4: 9.3×10^{-4} m

  30.6: a) 4.6×10^{21} b) 4.3×10^{-12} m

  30.8: a) $v_d = 7.5 \times 10^{-6}$ m/s b) $\tau = 2.1 \times 10^{-14}$ s

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 30

Current & Resistance

(*Conductivity and Resistivity & Resistance and Ohm's Law*)

Review…

- *Drift velocity…*

$$v_d = \frac{e\tau}{m}E$$

- *Electron current…*

$$i_e = \frac{n_e e \tau A}{m}E$$

- *Current…*

$$I \equiv \frac{dQ}{dt} = i_e e$$

Review…

- *Current Density…*

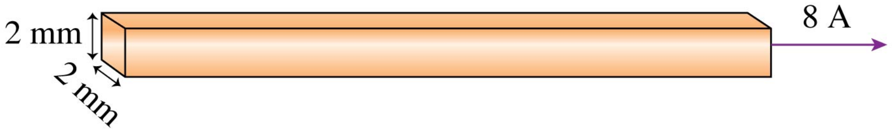
$$\boxed{J \equiv \frac{I}{A} = n_e e v_d}$$

- *Kirchoff's Junction Rule…*

$$\boxed{\Sigma I_{in} = \Sigma I_{out}}$$

Quiz Question 1

The current density in this wire is



$L = 2.0 \times 10^{-3}$ m

$L \times L = 4.0 \times 10^{-6}$ m²

$A = 4.0 \times 10^{-6}$ m²

$\frac{8\text{ A}}{4.0 \times 10^{-6}\text{ m}^2} = 2.0 \times 10^{6}$ A/m²

1. 4×10^6 A/m².
2. 2×10^6 A/m².
3. 4×10^3 A/m².
4. 2×10^3 A/m².
5. Can't tell without knowing the length.

30.4:
Conductivity and Resistivity

How is the current density, J, related to the E-field driving the current?

$J = n_e e v_d \qquad v_d = \frac{e\tau}{m} E$

$J = n_e e \cdot \frac{e\tau}{m} E$

$J = \left(\frac{n_e e^2 \tau}{m}\right) E$

$J = \sigma E$

30.4: Conductivity and Resistivity

How the current density, *J*, is related to the *E*-field driving the current:

$$\boxed{J = \sigma E}$$

where $\sigma = \dfrac{n_e e^2 \tau}{m}$ = conductivity

SI Units?

$$[\sigma] = \frac{J}{E} = \frac{A/m^2}{\Delta V/m} = \frac{1}{\Omega m}$$

$$\frac{\frac{A}{m^2}}{\frac{\Delta V}{m}} \quad \frac{A\cancel{m}}{m^{\cancel{2}}\Delta V} = \frac{A}{Vm} = \Omega \frac{1}{m}$$

30.4: Conductivity and Resistivity

How the current density, *J*, is related to the *E*-field driving the current:

$$\boxed{J = \sigma E}$$

Where $\sigma = \dfrac{n_e e^2 \tau}{m} = \text{conductivity}$

SI Units?

$$[\sigma] = \Omega^{-1} m^{-1}$$

30.4: Conductivity and Resistivity

How the current density, J, is related to the E-field driving the current:

$$\boxed{J = \sigma E}$$

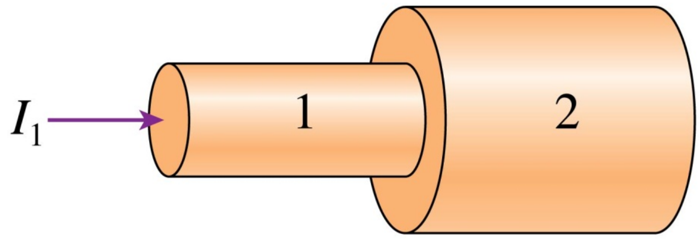
Notice:

1. *Current* is caused by the E-field exerting forces on the charge carriers.
2. The *current density* (& *current*) depend *linearly* on the *strength* of the E-field.
3. The *current density* also depends on the *conductivity* of the material.

Quiz Question 2

Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left.

How does current I_1 in segment 1 compare to current I_2 in segment 2?



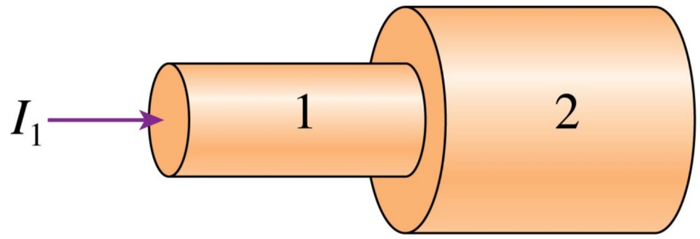
1. $I_1 > I_2$.
2. $I_1 = I_2$.
3. $I_1 < I_2$.
4. There's not enough information to compare them.

Kirchoffs Junction Rule

Quiz Question 3

Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left.

How does current density J_1 in segment 1 compare to current density J_2 in segment 2?



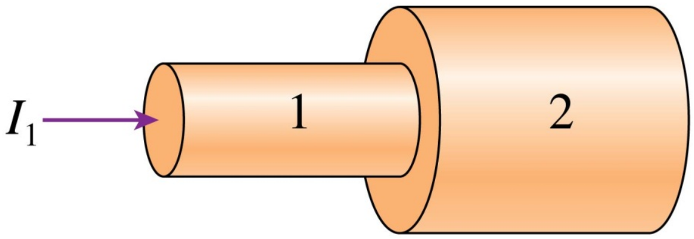
$J = \frac{I}{A}$

1. $J_1 > J_2$.
2. $J_1 = J_2$.
3. $J_1 < J_2$.
4. There's not enough information to compare them.

Quiz Question 4

Both segments of the wire are made of the same metal. Current I_1 flows into segment 1 from the left.

How does the electric field E_1 in segment 1 compare to the electric field E_2 in segment 2?



1. $E_1 > E_2$.
2. $E_1 = E_2$ but not zero.
3. $E_1 < E_2$.
4. Both are zero because metal is a conductor.
5. There's not enough information to compare them.

30.4:
Conductivity and Resistivity

Define the *resistivity*…

$$\boxed{\rho = \frac{1}{\sigma} = \frac{m}{n_e e^2 \tau}}$$

SI Units?

30.4: Conductivity and Resistivity

Define the *resistivity*…

$$\boxed{\rho = \frac{1}{\sigma} = \frac{m}{n_e e^2 \tau}}$$

SI Units?

$$[\rho] = \Omega \cdot m$$

30.4: Conductivity and Resistivity

Define the *resistivity*…

$$\boxed{\rho = \frac{1}{\sigma} = \frac{m}{n_e e^2 \tau}}$$

TABLE 30.2 Resistivity and conductivity of conducting materials

Material	Resistivity (Ω m)	Conductivity (Ω^{-1} m^{-1})
Aluminum	2.8×10^{-8}	3.5×10^{7}
Copper	1.7×10^{-8}	6.0×10^{7}
Gold	2.4×10^{-8}	4.1×10^{7}
Iron	9.7×10^{-8}	1.0×10^{7}
Silver	1.6×10^{-8}	6.2×10^{7}
Tungsten	5.6×10^{-8}	1.8×10^{7}
Nichrome*	1.5×10^{-6}	6.7×10^{5}
Carbon	3.5×10^{-5}	2.9×10^{4}

*Nickel-chromium alloy used for heating wires.

SI Units?

$$[\rho] = \Omega \cdot m$$

i.e. 30.6: The *E*-field in a wire

A 2.0 mm diameter aluminum wire carries a current of 800 mA. What is the *E*-field strength inside the wire?

$R = 1.0 \times 10^{-3}\ m$

$I = 800 \times 10^{-3} A$

$J = \sigma E$

$\frac{J}{\sigma} = E$

$J = \frac{I}{A}$

$A = \pi (1.0 \times 10^{-3} m)^2$

$J = 2.6 \times 10^{5} A/m^2$

$\sigma = 3.5 \times 10^{7}\ \Omega^{-1} m^{-1}$

$J = 2.6 \times 10^{5}\ A/m^2$

$E = 7.4 \times 10^{-3}\ V/m$

30.5: Resistance and Ohm's Law

How is the *current*, I, related to the *potential difference*, ΔV in a wire?

$$J = \sigma E = \frac{1}{\rho} E$$

$$E_s = \frac{-dV}{ds} \quad \therefore \quad |E_s| = \frac{\Delta V}{\Delta s} = \frac{\Delta V}{L}$$

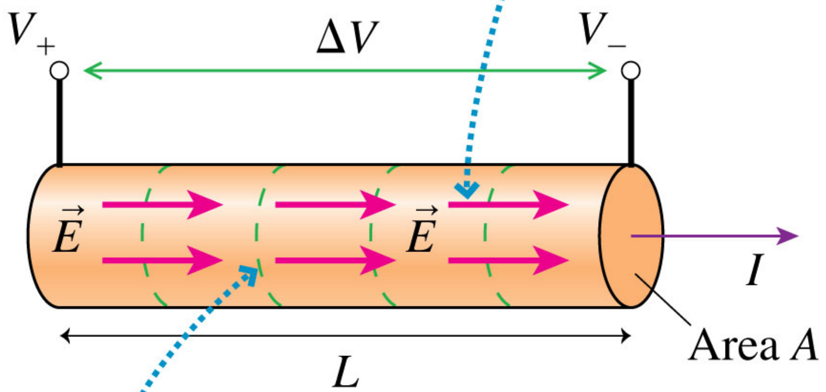
$$J = \frac{I}{A}$$

$$\frac{I}{A} = \frac{1}{\rho} \frac{\Delta V}{\Delta L}$$

$$I = \left(\frac{A}{\rho L}\right) \Delta V$$

$$R = \frac{\rho L}{A}$$

$$I = \frac{\Delta V}{R}$$



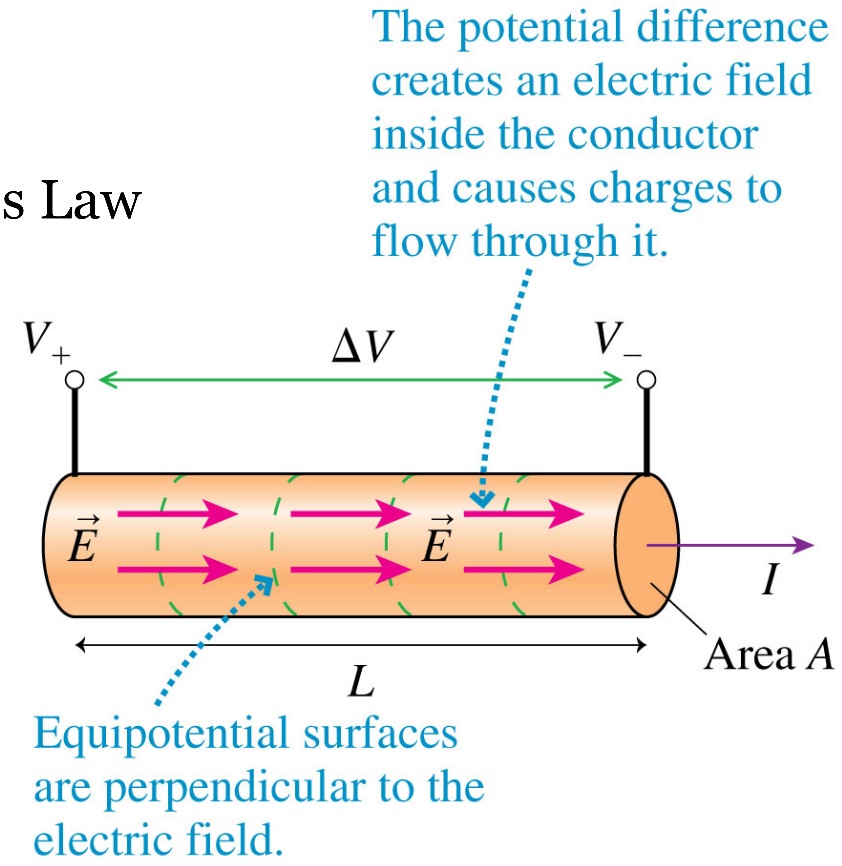
30.5:
Resistance and Ohm's Law

How is the *current*, I, related to the *potential difference*, ΔV in a wire?

$$\boxed{I = \frac{\Delta V}{R}}$$

- Ohm's Law

SI Units of R?



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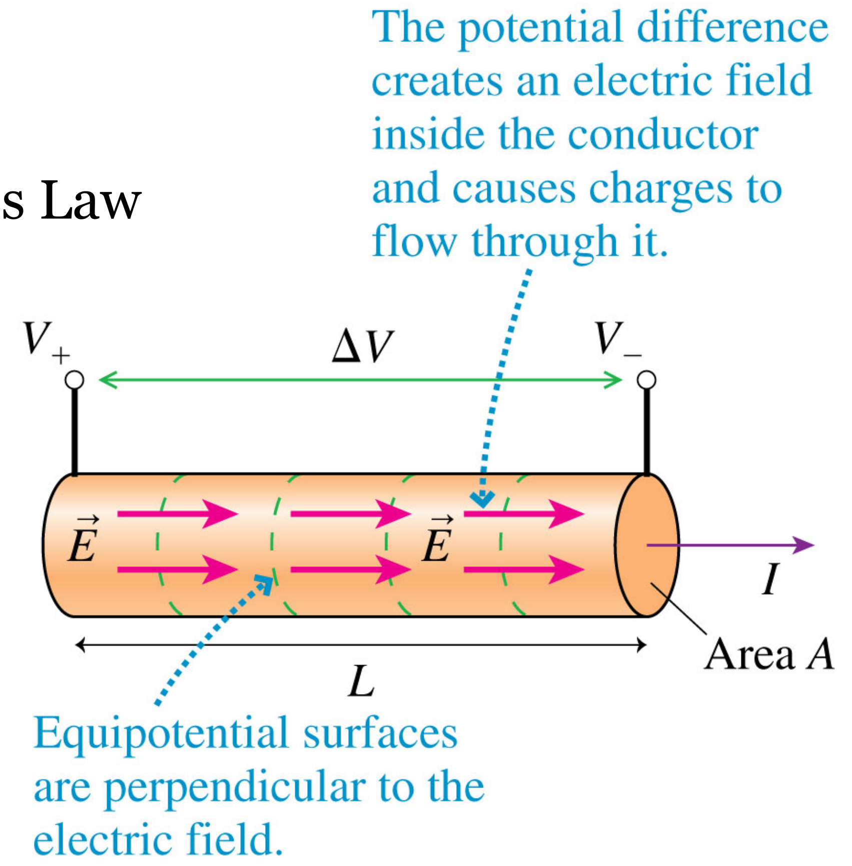


SI Units of R?

$$[R] = \Omega$$

30.5:
Resistance and Ohm's Law

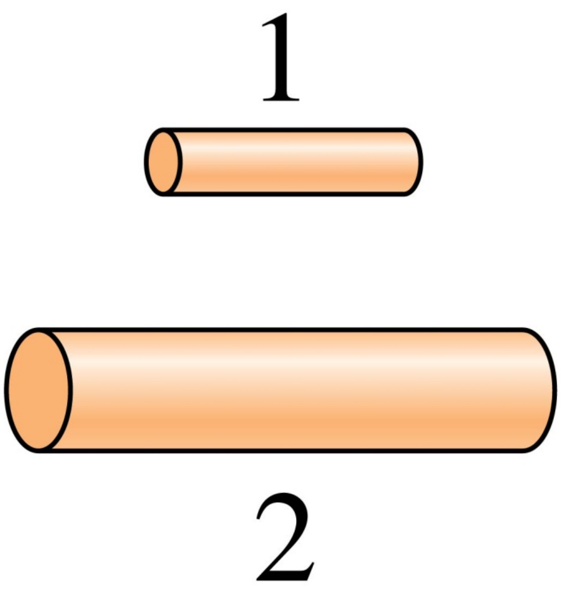
$$\boxed{R = \frac{\rho L}{A}} \longleftarrow \text{Resistance of a wire}$$

Notice:

- *Resistivity*, ρ, describes *just* the material.
- *Resistance*, R, characterizes a *specific piece* of the conductor with a *specific geometry*.

Quiz Question 5

Wire 2 has *twice* the length and *twice* the diameter of wire 1. What is the ratio R_2/R_1 of their resistances?



1. 1/4.
2. 1/2.
3. 1.
4. 2.
5. 4.

Resistance and Ohm's Law

- A battery is a *source* of potential difference ΔV_{bat}.
- The battery *creates* a potential difference $\Delta V_{wire} = \Delta V_{bat}$ between the ends of the wire.
- The potential difference in the wire ΔV_{wire} generates an E-field in the wire.
- The E-field establishes a current $I = JA = \sigma AE$ in the wire.
- The current in the wire is determined *jointly* by the battery and the wire's resistance, R to be:
  - $I = \Delta V_{wire}/R$